Claims

1. A method of using a laser output to rapidly remove target material from a target material location of a workpiece, the laser output removing a portion of the target material at a material removal rate, and the target material characterized by a temperature and a dimensional stability property, comprising:

applying heating energy in the form of a light beam to the target material location to elevate its temperature while substantially maintaining the dimensional stability property of the target material; and

directing for incidence on the target material location a processing laser output characterized by a wavelength, a beam spot size, an energy per pulse, a pulse width, and a pulse repetition rate that, in combination, are appropriate to effect removal of the target material, the combined incidence of the processing laser output and the heating energy on the target material location enabling the processing laser output to remove a portion of the target material at a material removal rate that is higher than a material removal rate achievable in the absence of the heating energy.

2. The method of claim 1, in which the method involves forming a via in the workpiece, the processing laser output is generated by a processing laser that is selected from a group consisting essentially of an ultraviolet laser, an IR laser, a green laser, and a CO_2 laser, and the heating energy is generated by a light source that is selected from a group consisting essentially of a diode laser, a diode laser array, an array of light emitting diodes, a fiber laser, an IR laser, an ultraviolet laser, a CO_2 laser, and a combination thereof.

3. The method of claim 2, in which the via is one of a blind via or a through-hole via.

4. The method of claim 2, in which the processing laser output is generated by a processing laser that is a diode-pumped, Q-switched solid-state laser, the processing laser output has a wavelength in the IR spectrum such that the wavelength is less than 2.1 microns, and the heating energy has a wavelength of less than 2.2 microns.

5. The method of claim 2, in which the processing laser output is generated by a processing laser that is a diode-pumped, Q-switched solid-state laser, the processing laser output has a harmonic output in one of the green spectrum and the ultraviolet spectrum such that the wavelength is less than 0.6 micron, and the heating energy has a wavelength of less than 2.2 microns.

6. The method of claim 2, in which the processing laser is selected from a group consisting essentially of a pulsed CO_2 laser and a Q-switched CO_2 laser, the processing laser output has a wavelength between about 9.2 microns and about 10.6 microns, the light source is a CO_2 laser, and the heating energy has a wavelength that is between about 9.2 microns and about 10.6 microns.

7. The method of claim 2, in which the processing laser is selected from a group consisting essentially of a pulsed CO_2 laser and a Q-switched CO_2 laser, the processing laser output has a wavelength that is between about 9.2 microns and about 10.6 microns, the heating energy has a wavelength that is between about 0.7 micron and about 3 microns, and the light source is selected from a group consisting essentially of a solid-state laser, a fiber laser, a diode laser, and a combination thereof.

8. The method of claim 2, in which the workpiece is a thin copper sheet, the processing laser output is generated by a laser selected from a group consisting essentially of a pulsed CO_2 laser and a Q-switched CO_2 laser, and the heating energy has a wavelength that is shorter than 2.2 microns.

9. The method of claim 1, in which the workpiece is a semiconductor wafer, the method involves dicing the semiconductor wafer, the processing laser output is generated by a processing laser that is selected from a group consisting essentially of an ultraviolet laser, a green laser, and an IR laser, and the heating energy is generated by a light source that is selected from a group consisting essentially of a diode laser, a diode laser array, a solid-state laser, a fiber laser, an array of light emitting diodes, and a combination thereof.

10. The method of claim 9, in which the processing laser is a mode-locked laser, the processing laser output has a wavelength that is between about 200 nm and about 1600 nm, the heating energy has a wavelength that is between about 0.7 micron and about 2.2 microns, and the light source is selected from a group consisting essentially of a diode laser, a diode laser array, a fiber laser, and a combination thereof.

11. The method of claim 1, in which the workpiece includes multiple, different target material locations and in which the processing laser output removes from the different target material locations target material whose temperature is elevated by the heating energy, thereby removing target material at the different

target material locations at a workpiece throughput rate that is higher than a workpiece throughout rate achievable in the absence of the heating energy.

12. The method of claim 1, in which the light beam, when illuminating the target material, has a light beam spot size and the processing laser output, when incident on the target material, has a processing laser output spot size, the light beam spot size being between about 50% and about 1000% of the processing laser output spot size.

13. The method of claim 1, in which the light beam has a light beam wavelength and the processing laser output has a processing laser output wavelength, and further comprising a light beam combining optical element that combines the light beam and the processing laser output and processes the light beam before it illuminates the target material and processes the processing laser output before it is incident on the target material, the light beam wavelength and the processing laser output wavelength defining a wavelength range that is within an operating wavelength range of the beam combining optical element.

14. The method of claim 1, in which the workpiece is a multilayer material.

15. The method of claim 1, in which the processing laser output and the heating energy are directed to the target material location by multiple, separate beam steering and focusing optics.

16. The method of claim 1, in which the processing laser output has a spot size that is between about 1 micron and about 200 microns.

17. The method of claim 1, in which the processing laser output has a pulse repetition rate that is between about 1 Hz and about 150 MHz.

18. The method of claim 1, in which the processing laser output has a pulse energy that is between about 0.01 μJ and about 1 J.

19. The method of claim 1, in which the heating energy comprises a continuous wave of energy during its combined incidence with the processing laser output on the target material location.

20. The method of claim 1, in which the processing laser output and heating energy are applied to the target material location for, respectively, a processing laser output period and a heating energy period, and in which the heating energy period is between about 50% and about 100% of the processing laser output period.

21. The method of claim 1, in which the heating energy comprises a series of pulses having a repetition rate of between about 1 Hz and about 200 kHz during its combined incidence on the target material location with processing laser output.

22. The method of claim 1, in which the heating energy has an average power of between about 0.01 W and about 1000 W.

23. The method of claim 1, in which the heating energy has a heating energy power level that is modulated between about 50% and about 100% of a peak power level during the combined incidence of the processing laser output and the heating energy on the target material location.